The Use of Modeling & Simulation (M&S) Tools in Acquisition Program Offices: Results of a Survey

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Appendix B – DOT&E Brief, Taxonomy and Survey Template **Attached**

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INTRODUCTION

Purpose

The DoD Deputy Director, Operational Test and Evaluation / Live Fire Testing (DDOT&E/LFT), through the DOT&E, tasked Hicks & Associates (HA&I) to conduct a survey of models and simulations (M&S) being used in support of defense acquisition programs. The tasking came as the direct result of issues first raised in an article which was published in DSMC's Program Manager (PM) Magazine in their March – April 1999 issue entitled "Meet MASTER: Modeling & Simulation Test & Evaluation Reform: Energizing the M&S Support Structure". The MASTER concept includes a number of proposals including the formation of an M&S Consortium and the possibility of funding this Consortium by tapping into the budgets of the acquisition systems which would benefit from M&S. However, when the question of how much is currently being spent in support of M&S, and related questions as to who is spending it and for what, there was little, if any, comprehensive data upon which to base a response. The purpose, then of the Hicks tasking was to identify, characterize, and determine the extent of M&S applications across a range of program office activities -- from concept exploration and engineering development through production and logistical support to systems in the field.

Objectives

Key objectives of the survey included identifying the number and types of models in use, where they originated, how they are being applied in support of the acquisition program, and the program offices' level of expenditure on M&S tools. In addition, the survey sought insights into how M&S activities are managed within program offices, including the identification of potential 'best practices' and problem areas.

Motivation

The project was motivated by several factors. First, DoD leadership has focused over the past several years on developing a High Level Architecture (HLA), and related management structures such as the Defense Modeling and Simulation Office (DMSO), to foster simulation interoperability and efficiencies across DoD components. These efforts are focused largely on creating the technical environment and infrastructure necessary to facilitate future M&S activities. In contrast to this, the LFT&E leadership sought to understand more about how, in actual practice, models and simulations are actually viewed and utilized from the Program Managers' perspectives; not theory, not policy, but in actual day-to-day application.

New DoD policy emphasis on Simulation-Based Acquisition (SBA) is a second motivating factor. To the extent DoD leadership plans increasing use of M&S to substantially reduce the time, resources, and risks associated with the acquisition process, a better understanding of how M&S is currently used at the program level could provide a useful point of departure. Indeed, despite the apparently growing role of M&S in a number of areas, DoD lacks basic information on the extent of M&S use in support of

acquisition program offices. DOT&E therefore sought, through this survey, to improve the general level of understanding of how M&S tools are being used in today's program offices.

Another motivating factor was cost. An initial hypothesis going into the survey was that, despite recent efforts to focus on DoD-level expenditures supporting HLA and attempts at strengthening M&S oversight in the Services, most M&S expenditures still tend to be made on a decentralized basis through individual program offices. Concern was expressed that DoD may be paying more than once for the same models. Further, the issue of whether existing models were being re-used was of interest. Sorting out program office expenditures for M&S was thus an important objective.

A final, but by no means the least important, motivation for this survey was to better inform future policies involving the interrelationships and balance between modeling and simulation and more traditional forms of test and evaluation (T&E) -- a complex issue requiring continuous reassessment by the operational and live-fire test communities.

Projected Results and Outcomes

DOT&E expects this survey to raise cross-service knowledge of M&S is used at the acquisition program level. Where the survey indicates that the M&S information desired is not available, the report may suggest the need for further visibility into M&S activities and/or improvements in routine data collection. Anecdotal data reflecting lessons learned or best practices should be of use to program managers. Best practices can also be used for benchmarking future M&S-related policies and procedures. Where conclusions and recommendations are drawn, the survey may contribute to an improved process for access to, and coordination of, M&S information and provide a catalyst to stimulate more effective DoD investments in M&S support.

As the survey had gathered and evaluated sufficient data to provide preliminary insights, a series of briefings were initiated to the DOT&E, then to the DMSO office, the DDR&E, the Service Acquisition Executives, and eventually to the USD(AT&L). As a result of these briefings, tangible positive results have already been realized. For example, the Undersecretary of Defense for Acquisition, Technology and Logistics (USD(AT&L)) directed his staff to draft changes to the acquisition instructions in response to insights highlighted in the survey results. Furthermore, the Service Acquisition Executives are co-sponsoring, with DOT&E, a series of Pilot Projects that provide tangible, real-life opportunities for M&S to better support the acquisition process.

Overview

This report begins with a description of methodology and scope, including the organization of the survey, the rationale for the programs selected for sampling, access to data, and methodological challenges. The findings are then described in four areas: the characterization of model types and uses; M&S management; M&S costs; and model verification, validation and accreditation (VV&A) activities. The positive aspects of

M&S evolution are then reviewed, followed by current issues and challenges. The report concludes with recommendations in two categories: areas where DOT&E can take unilateral action; and recommended actions where assistance from outside organizations would be required.

METHODOLOGY AND SCOPE

Collecting real-time data on M&S activities supporting DoD acquisition programs presented several challenges. First, modeling and simulation tools are applied to a wide range of activities, with the number of tools in use totaling in the hundreds, if not thousands; thus, categorizing M&S activities was a necessary starting point. In addition, with over 200 acquisition programs underway, selecting a small, but representative sample of programs for review was also imperative. After a series of discussions with DDOT&E/LFT, it was determined that a survey of current programs in the acquisition process would be the most viable method of answering the questions posed. With in excess of 200 acquisition programs currently underway in the DoD, it was clear that the survey would have to either choose to do a superficial evaluation of all programs, or to select a representative subset of programs and evaluate them in depth. The latter approach was the unanimous choice. It was decided that a total of 22 programs would be evaluated which would cut across all military services, air, land and sea platforms, weapons, C4I systems, and large ACAT ID programs as well as smaller programs that were at the beginning or nearing the end of their development cycle. These evaluations were supplemented by interviews of program office and other Service and agency personnel with M&S and/or acquisition experience. A list of personnel interviewed and the documents reviewed during a literature search are contained in Appendix A.

The Survey

The categories and descriptions of M&S-related activities to be surveyed were drawn from the "*Taxonomy of M&S Types and Applications in the System Acquisition Process, December 1998."* This taxonomy is contained in *"A Roadmap for Simulation Based Acquisition,"* produced by the Joint Simulation Based Acquisition Task Force under the auspices of the Acquisition Council, DoD Executive Council for Modeling and Simulation (EXCIMS). Though still regarded as a work in progress, this taxonomy reflected the most recent and detailed effort of the M&S community to categorize a large number of distinct models and tools. A list of specific questions was developed, based on requirements for data identified by the sponsor. These categories and questions provided a uniform framework for the survey. The collection of basic M&S-related data was emphasized over analysis of the models themselves or their effectiveness. (The survey framework, however, did provide a limited opportunity for subjective or anecdotal inputs on the quality and utility of the M&S tools in use.) In addition, the survey sought descriptions of how M&S activities are managed within the program office. The survey template, questionnaire, and taxonomy are contained in Appendix B.

Twenty-two programs were identified for the survey including representative programs from the Services and a mixture of platforms, weapons, and C41SR systems. The

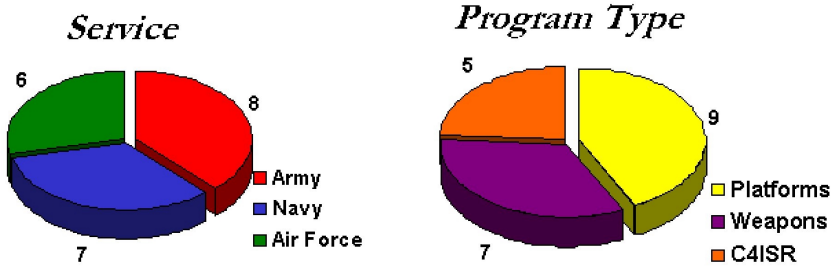
programs selected also varied in size, age and technical complexity, providing a broad cross-section of acquisition programs.

Project goals and methodology were briefed to the Service acquisition chains of command beginning with Service Acquisition Executives (SAEs) and their staffs, including the Program Executive Officers (PEOs), and the Program Managers or their representatives in the Program Offices. The program offices were given 30 days to respond (most received extensions). They utilized a mixture of internal, contractor, and other government support to develop their response. Of the twenty-two programs selected for the survey, twenty-one programs responded and cooperated with the study team. The only program initially selected which did not participate, the Joint Strike Fighter (JSF) program, did not due so primarily due to the proprietary nature of the competitive development that was ongoing between the two major teams, thereby making the discussion and dissemination of this information problematic. The twenty-one programs are listed in Figure 1.

Figure 1: Summary of Survey Responses to Date

Program	Component	System Type	Current Status*	FRP Date*
Crusader	Army	Platform	MSII decision 2001	1QFY06
Comanche	Army	Platform	MSII decision FY02	1QFY07
M1A2 Upgrade	Army	Platform	FRP	3QFY94
ATACMS Blk II/BAT	Army	Weapon	LRIP	3QFY00
Javelin	Army	Weapon	FRP	3QFY97
SADARM	Army	Weapon	LRIP	4QFY98
FAAD C2	Army	C4ISR	FRP	3QFY95
C2 Vehicle	Army	C4ISR	LRIP	1QFY00
F/A-18 E/F	Navy	Platform	LRIP	3QFY00
V-22 Osprey	Navy/USMC	Platform	LRIP	2QFY00
LPD-17	Navy/USMC	Platform	EMD	3QFY07
AIM-9X	Navy	Weapon	LRIP	1QFY02
AN/BSY-2 (SSN-21)	Navy	C4ISR	Sea Trials on SSN-22 (USS *CONNECTICUT*)	N/A
UHF Follow-On	Navy	C4ISR	Completing FRP	4QFY88
SLAM-ER	Navy	Weapon	FRP	2QFY99
F-22	USAF	Platform	LRIP	3QFY03
B-2	USAF	Platform	IOC	N/A (did not enter FRP)
EELV	USAF	Platform	MSII Decision FY99	2QFY03 (MSIII decision 1QFY03)
ABL	USAF	Weapon	MSII decision FY03	2QFY05
SBIRS	USAF	C4ISR	MSII decision 1996	First GEO sat deliv. FY02; HEO FY03; LEO FY-04
SFW P3I	USAF	Weapon	FRP	3QFY96

Source: DOT&E FY98 Annual Report to Congress



Program office responses were provided directly to H&AI. The results outlined below reflect program office responses to the formal survey supplemented with informal comments and insights related to M&S from PEOs and others in the Service acquisition chains and the Office of the Secretary of Defense (OSD). Data extracted during the literature search are also integrated into this report.

Limitations

It is important to note several limitations in attempting to draw conclusions and generalizations from the programs surveyed. First, while they represent a cross-section of programs, the programs surveyed also cover some twenty-five years or more in program age. During this period, significant changes in M&S, and other information technologies, as well as numerous changes in acquisition policies and procedures have affected program offices. Under these circumstances, efforts to compare M&S activities among programs must be carefully considered.

The availability of M&S-related data appears to have been affected by a number of variables, including program age, record keeping procedures, staff continuity and knowledge of program history. In addition, the methods used within each program to complete the survey also varied, as well as the background and experience of those who completed the survey. In some cases, for example, programs offices have personnel dedicated full time to coordination and oversight of M&S activities; in other programs, the point of contact for the survey had only limited M&S experience. Similarly, M&S experts may have been unfamiliar with accounting and budgeting procedures and/or how to gain further insights into M&S costs.

The survey involved a matrix of M&S categories and questions providing a total of 168 possible data cells to be filled-in by the program offices. Many program offices appeared to use a distributed approach to the survey, dividing the work among experts from the program office, contractors, and Service laboratories and FFRDCs. Programs also each set their own limits (e.g. 80 hours) on how much time would be devoted to this effort. This process of distributed data entry inherently produces data of uneven quality. Variations in personnel background and expertise, combined with limitations of time and availability of data, also contributed in some cases to empty data cells, incomplete entries or entries not comparable across the sixteen program matrices.

One of the most important caveats about the data is that the survey results represent only a point in time. It is not possible to use the data to draw conclusions about trends or changes in M&S development and use.

Despite such limitations, the survey produced objective and anecdotal data of potential use to program managers, the M&S community, and acquisition policymakers in general. As an initial effort, it highlights what is known and unknown about M&S activities at the program level; and with a modest level of analysis suggests potential opportunities for improvement and identifies issues for further investigation.

FINDINGS AND CONCLUSIONS

Overview

The wide variety of programs selected for the survey was a major plus, resulting in a broad and representative spectrum of inputs. However, each program is a product of specific circumstances involving different acquisition strategies, acquisition policies, relationships to other programs (as in follow-ons), funding profiles, and whether the program is in early development or in post-production support.

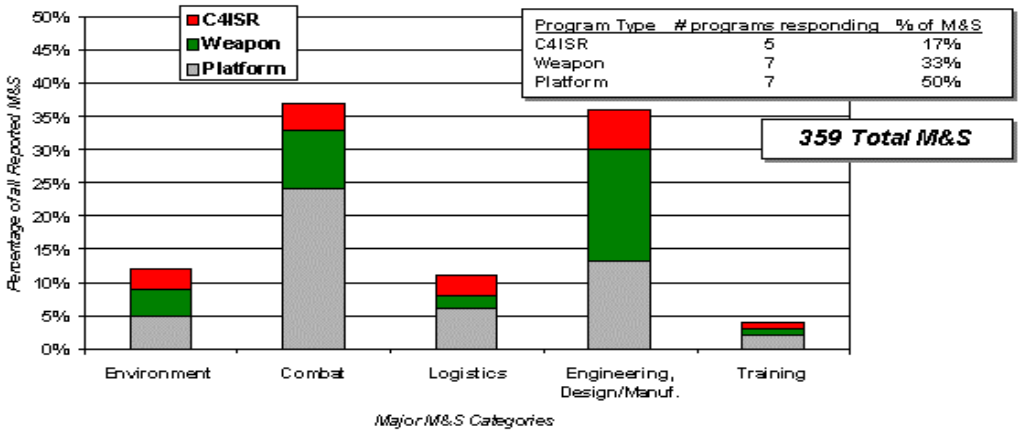
The survey represents a limited sample of acquisition programs at a specific point in time from which conclusions cannot easily be drawn. The conclusions and recommendations outlined below should be considered in this context.

Characterization of Model Types and Uses

This section of the report characterizes the types of M&S that are reported in use by the responding programs. Such a characterization is of interest since it provides insight into potential opportunities for developing common models or community-standards and the types of expertise that may be needed for their development.

Even though the taxonomy used for the survey is generally accepted within the M&S community, there is some overlap among model types. Further, the category definitions are quite detailed but still are subject to interpretation. As a result, program offices reported the same model under different categories. Every attempt was made to adjudicate these variations during analysis of the data. Figure 2 shows the distribution of M&S reported by the program offices by model category.

Figure 2: M&S Characterization



- *Types of M&S used driven partly by program type*
- *"Platform" programs utilized more total M&S assets and comparatively higher percentage of logistics and combat M&S types*
- *"C4ISR" programs utilized comparatively higher percentage of training M&S*

The Engineering Design/Manufacturing (ED/M) and Combat M&S categories, respectively, comprise the most M&S. ED/M M&S include Virtual 3-D Layouts, Virtual Manufacturing Plant Simulations, and Constructive Engineering and Manufacturing Process Models. The predominance of Combat and ED/M M&S is not surprising considering that acquisition program offices focus on system design and development rather than activities associated with later phases of the system life cycle, such as training and logistics.

Engagement M&S constituted the large percentage of Combat M&S. Several weapons systems and platform programs reported using more than one engagement model. Closer examination of this data revealed that the need for different engagement models with a program probably arose from needing different levels of fidelity for different purposes and the need to address system performance across a variety of threats. M&S in both the engagement and threat categories tended to rely on physics-based modeling.
The next largest category of Combat M&S was Virtual models which included Hardware in the Loop (HWIL), Man in the Loop (MITL), and virtual system simulations. Survey results indicated that most of these simulations were being used to support testing and/or training. Of special note, the AIM-9X, ATACMS BAT, and SLAM-ER program inputs described using the HWIL facilities to develop pretest predictions and to facilitate post-test analysis. The linking of HWIL to MITL capabilities represents an opportunity to support testing and training in a "system of systems" context using M&S. For example, the SLAM-ER program intends to link its HWIL to the F/A-18 MITL simulation so that a pilot can practice flying a weapon from a platform to a target. HWIL capabilities have benefited from the investment of corporate capital and the leveraging of that investment by government customers building on-site government HWIL facilities.

The number of environment models may seem unusually low. However, representations of environments such as terrain, weather, and oceans are included integrally in many of the Combat M&S. Also, the data showed that several programs are now using the some of the same Environment M&S (e.g., the LOWTRAN model for atmosphere). It is possible that over time, several M&S have been incorporated into or reduced to a single model.

Platform programs used the most M&S. This observation appeals to common sense since ships, aircraft, and tanks require complex integration of diverse subsystems, interaction with multiple environments, face multiple threats, and entail many man/machine interface issues. For the same reasons, platform programs used relatively more combat and logistics models than weapons and C4ISR programs.

C4ISR programs used a relatively higher percentage of training M&S than DID platform and weapons programs. This result may be due to the common practice of evolving a C4ISR system from its virtual representation in simulation to the actual functional capability with training occurring throughout the simulation evolution. For instance, the M&S suite for the FAAD C2 program steps from a simulation of end-to-end system

functionality to a simulation which evaluates system effectiveness to a training and exercise capability that can be used in the field or in garrison.

If, rather than sorting by program type, the data are sorted by program maturity, it is evident that the types of M&S currently in use by a program office depends on where the program is in the acquisition process. For example, the M1A2 Upgrade program (FRP 1994) is using many more test, training, and logistics simulations than the LPD-17 (FRP 2007) program that is using primarily engineering and combat M&S.

Over 25 M&S were used by more than one Program. The commonality was strongest within program types, e.g., weapons systems using LOWTRAN. Also some prime contractors used the same model across different programs.

Use of common models can be a positive factor for the acquisition community since it presents an opportunity for a common basis of understanding and evaluation. It also affords an opportunity for cost sharing among programs. However, it is desirable for the commonly used models to be the best model for a particular purpose, i.e., to insure that RELEX is, indeed the best reliability model for the Programs that are using it. For example, the 1999 Defense Science Board (DSB) study on T&E noted that many of the models in use today were developed more than twenty years ago when computing technology limited algorithmic approaches and the threats and system capabilities were much different. Another key question to consider concerning common model use is whether the model has been certified for its intended use and whether the intended use is within the model assumptions.

Conclusion: Requirements for M&S vary by program type and program maturity. Availability of a common set of M&S could benefit program offices by allowing them to conserve schedule time and funding.

M&S Management

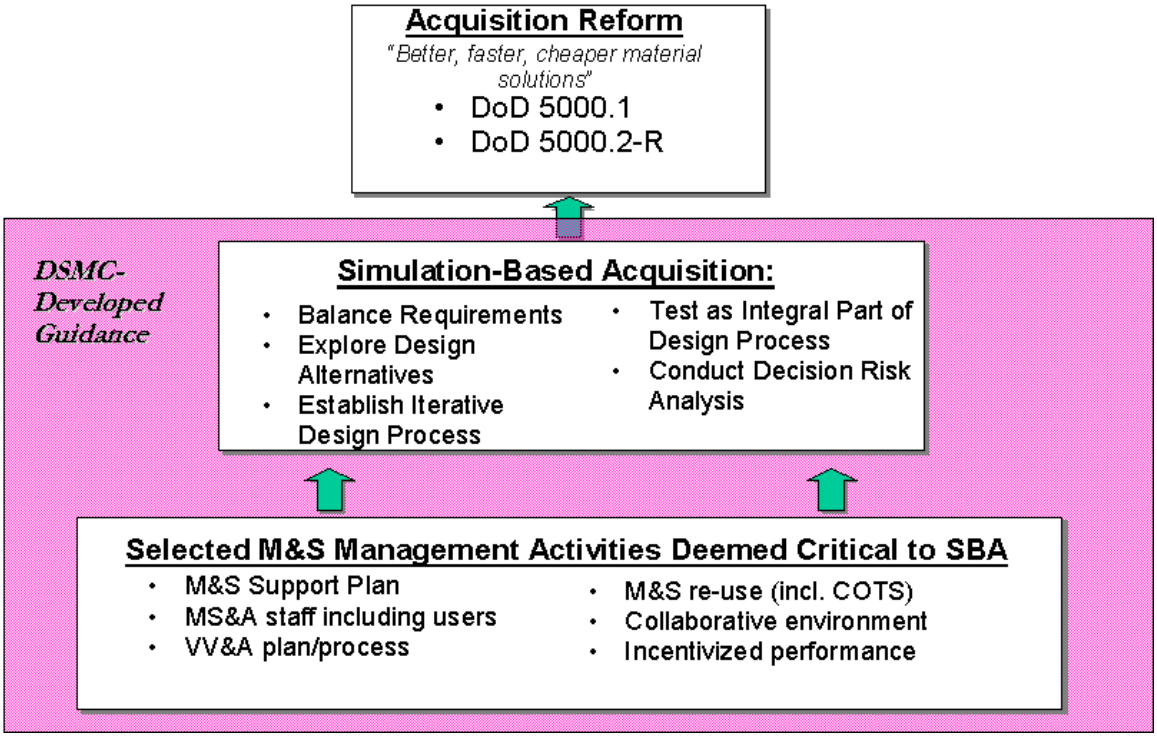
According to the Defense Systems Management College (DSMC) report, *Simulation Based Acquisition: A New Approach* (December 1998), SBA "is an iterative, integrated product and process approach to acquisition, using modeling and simulation, that enables the warfighting, resource allocation, and acquisition communities to fulfill the warfighter's materiel needs, while maintaining Cost As an Independent Variable (CAIV) over the system's entire life cycle and within the DoD's system of systems."

The DSMC report goes on to say that there are five essential features, or enablers, of an SBA process that need to be implemented by the acquisition community. First, "early user involvement is essential in defining, refining, and balancing requirements. This is the critical first step in producing better, faster, and cheaper material solutions." Second, a synthetic environment allows an integrated product and process design (IPPD) team to "concurrently explore greater numbers of possible material solutions than is possible within the current acquisition process. Third, the iterative nature of the SBA design process will enable IPPD teams to converge systematically on optimal solutions more

efficiently than is currently possible. Fourth, SBA will support changing the role of testing into that of being an integral part of the design process. Finally, SBA supports informed tradeoff analyses through a Decision Risk Analysis process."

The DSMC report then provides detail about the activities that constitute each of these five enablers. These activities include (but are not limited to) development of an M&S Support Plan, creation of a Modeling, Simulation and Analysis (MS&A) staff that includes users, preparation and implementation of a VV&A plan/process, re-use of M&S across acquisition program phases and across programs to include the use of Commercial Off-the-Shelf (COTS) tools, development of a collaborative environment, and incentivizing the performance of the M&S developers and users. Although implementation of these activities alone is not sufficient for SBA success, they are deemed necessary in the DSMC report. Figure 3 summarizes the SBA precepts and these enabling activities.

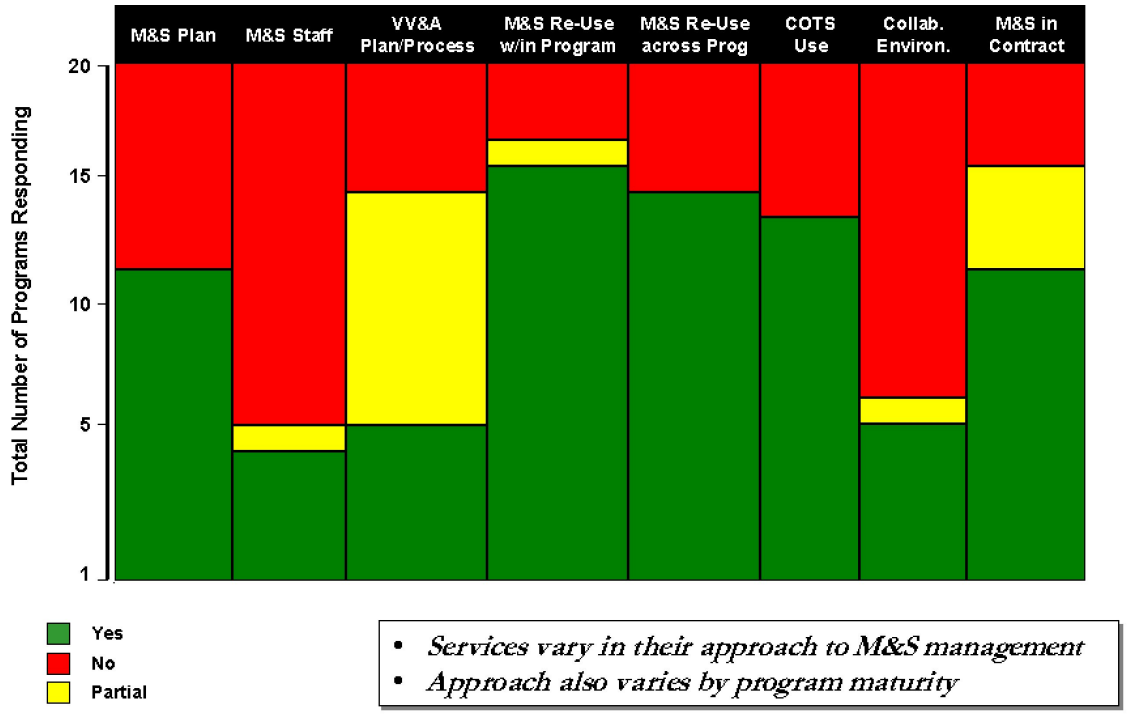
Figure 3: M&S Management Requirements for SBA, Acquisition Reform



The survey questions asked about the status of each of these activities within the Program Offices. Data concerning M&S management provide insight into the current state of implementation of the SBA vision. Depending on one's perspective, the resulting answers, summarized in Figure 4, are either good news or bad news for the status of SBA implementation. Across the board, roughly half of the surveyed programs reported conducting the activities that are considered necessary to SBA success. Not surprisingly, the newer programs reported engaging in more of these activities than the older or legacy

programs. Implementation of these activities varied some by Service. For instance, the Army programs reported a higher number of these activities as ongoing than the other two Services.

Figure 4: Incorporation of Selected M&S Management Activities



Many of the programs have developed M&S Support Plans that provide detailed information about the M&S that are being used within the program. However, these plans do not usually address requirements for future M&S growth nor identify the funding necessary to accomplish those improvements.

A former Director of the Defense Modeling and Simulation Office noted that having M&S experts within the staff of a Program Office is critically important to the appropriate and successful development and use of M&S. A few of the programs reported the existence of M&S staffs and others noted that they had formed M&S IPTs that included members of the user community. These IPTs were responsible for determining how M&S would be applied, as well as defining requirements for future M&S development.

Despite the existence of many Validation, Verification and Accreditation (VV&A) policy documents, such as DoD Instruction 5000.61, "DoD Modeling and Simulation Verification, Validation, and Accreditation," few of the programs had implemented overarching VV&A processes, as shown in Figure 4. Many programs had VV&A'd one or more of their M&S. VV&A is discussed in more detail later in this report.

Figure 4 shows re-use of M&S across acquisition phases of programs and across acquisition programs. M&S re-use across a program's acquisition phase may have been underreported since, as noted earlier in this report, survey respondents tended to be focused on the "here and now." Newer programs, such as LPD-17, noted their intent to mature and use the same core set of M&S throughout the system lifecycle. Legacy programs, such as M1A2, used models originally developed by their predecessor programs, e.g., the M1A1. M&S re-use across acquisition programs also occurred across programs that had the same prime contractor, e.g., the F-15 and the F-18E/F. Although the re-use columns of Figure 4 indicate that the majority of the programs in the survey were re-using models, less than 20% of the reported M&S were used by multiple programs in the survey.

Another instance of model re-use occurs when a program uses COTS packages. Over 75% of the programs reported using COTS M&S. In particular, COTS tools that supported engineering design and/or manufacturing, such as Pro E, CATIA, and Unigraphics were prevalent. As with the more program-specific cases of model re-use, COTS can provide a common framework for insight and analysis.

As Figure 4 shows, to date, collaborative environments have been implemented by less than 30% of the program offices surveyed. The survey results indicated that even the terminology, "collaborative environment," is not well understood. Rather than interpreting collaborative environment as an overarching architecture that facilitates the linkage of M&S across distributed locations and organizations, to several program offices the term connoted a collegial work environment in which IPTs shared information. For the few programs that have implemented or begun to implement meaningful collaborative environments there were some encouraging success stories. For instance, the Javelin Program had started the evolution towards a collaborative environment by developing an Integrated Test and Simulation Network. This network connects the program office, prime contractor, the Army Missile Command Research Development and Engineering Center, the Redstone Technical Test Center, the Javelin user, and the Army Infantry School Training and Doctrine Command. This collaborative environment gave the program timely access to the expertise required for engineering design and testing. It will also support remote training.

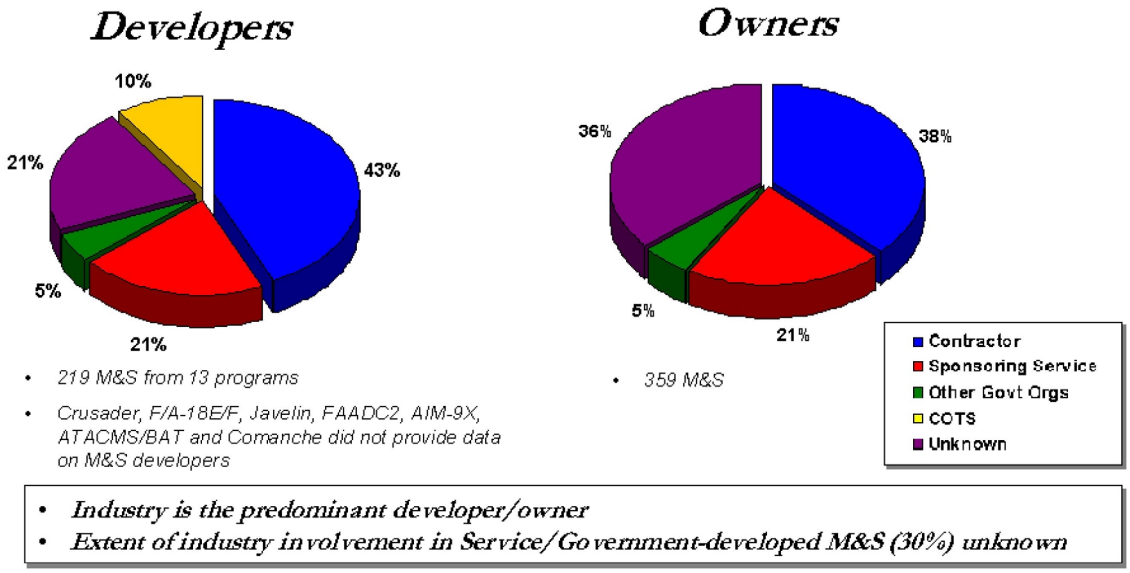
Another example of a collaborative environment is found within the LPD-17 program. One of the newest programs in the survey, LPD-17 implemented an Integrated Product Data Environment based on "tailored applications of COTS products and commercially-available foundation systems (CAD and PDM)." All personnel involved in any way in the LPD-17 Program can use the environment to access and work with program management, requirements, and engineering design information and models. The State of Louisiana provided the funding for LPD-17's collaborative environment.

Finally, as reflected in Figure 4, the survey results showed that slightly more than half the programs included M&S activities in their prime contractor's Statement of Work. This observation may explain why several program offices indicated that M&S development costs were not separable from investments in other program activities -- if M&S are not

addressed as separate tasks under the SOW, it is likely to be difficult for the government to track the associated costs. Only one program office, Crusader, reported incentivizing the contractor for M&S-related efforts.

Another M&S management issue of interest to the study sponsor was the development and ownership of M&S. The survey results showed that industry is the predominant developer of the M&S used by the program offices. In addition, industry retains ownership of nearly 40% of the M&S included in the survey. Figure 5 summarizes M&S developers and owners based on survey data.

Figure 5: Developers & Owners



Thirteen of the twenty-one programs participating in the survey supplied data about who developed the models. Contractors developed nearly half of the M&S described by these 13 program offices. Over 75% of these M&S, i.e., more than 60 M&S, were developed by the program's prime contractor or one of its team members. For example, Boeing or Bell developed several M&S for the V-22 program, Hughes developed M&S for the UHF Follow-On and Lockheed Martin developed M&S for the F-22 program. Other contractors developing M&S for the programs included the Aerospace Corporation, Aerojet, Logistics Management Institute, RAND, and SAIC. Small companies, software development companies and universities accounted for the remaining development.

Twenty-three percent of M&S were developed by an organization within the program's sponsoring Service. The Army developed the highest percentage of these models, using the Army Research Lab, Army Materiel Systems Analysis Activity, components of the Training and Doctrine Command (TRADOC), Space and Missile Defense Command (SMDC), and U.S. Forces Command (FORSCOM). The Navy followed with the next highest percentage of Service-developed M&S relying on the Naval Undersea Warfare Center, Naval Surface Weapons Center, and NAVAIR. The survey results did not indicate whether any of these Service organizations used industry support in developing

the models. Other government organizations also contributed to the development of M&S for the Programs. These entities included the Department of Energy's National Labs, National Institute for Standards and Technology (NIST), and National Aeronautics and Space Agency (NASA).

Ownership data were provided for over 300 M&S. These data show that the contractor who developed and/or is using the assets owns the largest percentage (38%) of M&S. This 38% included ownership of COTS tools where ownership means having a license for the package. Contractor ownership may become an issue when M&S are considered proprietary. One of the highest numbers of contractor-owned, proprietary models on a single program occurred with the Space-Based Infrared Systems (SBIRS) and the Aerospace Corporation. In this case, the contractor is working with the government providing architectural insight and information on design trades. It may be that the nature of the government/contractor relationship warrants the proprietary nature of the models.

Conclusion: Some of the management activities that are considered necessary to full realization of the SBA vision are being implemented. These activities are particularly in evidence on the new acquisition programs in the survey. However, implementation of these activities alone is not a sufficient condition for SBA to succeed.

Industry plays the key role in development of M&S, although the extent of this role does vary somewhat by Service. Industry also retains ownership of a large percentage of M&S. *This fact is worth some consideration in the event that a proprietary classification prevents visibility into the M&S or negatively impacts the ability to link models for "system of system" evaluation purposes.*

Validation, Verification and Accreditation Efforts

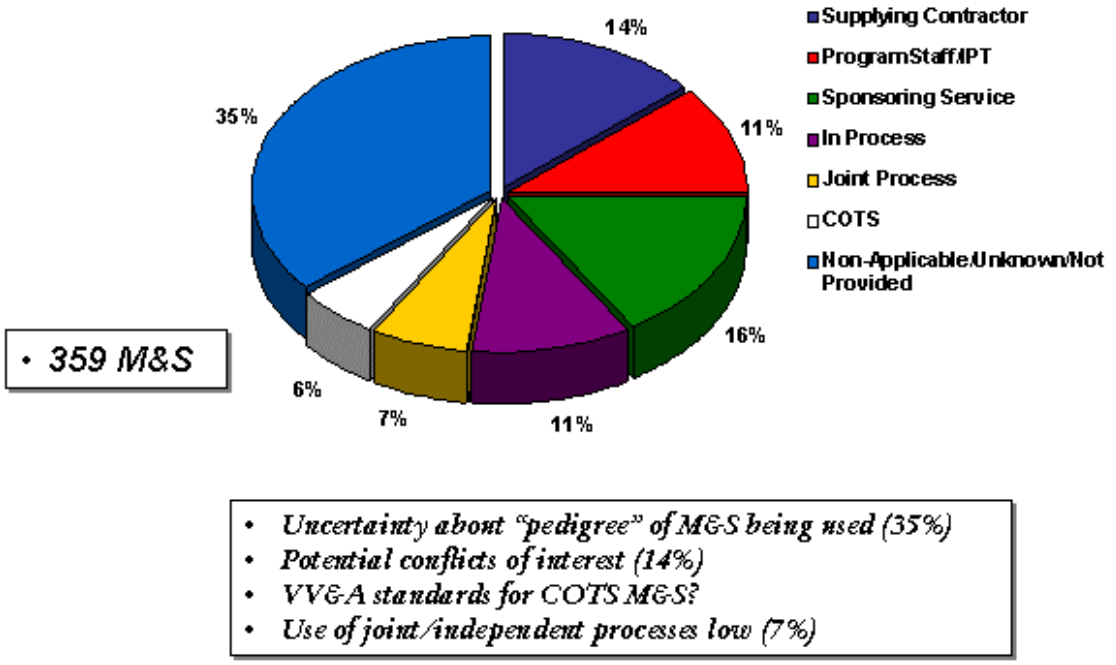
Validation, Verification, and Accreditation (VV&A) efforts appear to be challenging, at least based on survey results. The extent of VV&A activities varied significantly across the surveyed programs. In addition, the technical approach and expertise involved in program office VV&A efforts varied.

Referring to the DSMC Report, "*Simulation Based Acquisition: A New Approach"* and the *DoD M&S Glossary,* validation is the process of determining the degree to which a model or simulation is an accurate representation of the real world from the perspective of the intended uses of the model or simulation. Verification is the process of determining that a model or simulation implementation accurately represents the developer's conceptual description and specification. Verification also evaluates the extent to which the model or simulation has been developed using sound and established software-engineering techniques. Accreditation is the official certification that a model or simulation is acceptable for use for a specific purpose.

Implementation of these three processes is intended to provide a decision-maker with confidence in the model results. Figure 6 summarizes the status of VV&A efforts among

the programs in the survey. The growing role of M&S in acquisition and the potential of VV&A to increase a decision-maker's confidence make it somewhat surprising that the VV&A status of 35% of the M&S was unknown or at least was not available for the survey. *This result leads one to question whether the model users know and understand the limits and frailties of the models and whether those limits are taken into account when basing engineering design or operational decisions on the model outcomes.* Similar questions arise when considering the VV&A status of the COTS packages used by the Programs. The VV&A "status" ascribed to most COTS packages was "not applicable." This status is an acceptable one when the COTS user knows the pedigree of the package including its strengths, weaknesses, and limits. It is also acceptable when the COTS package is used to facilitate some other M&S function, e.g. visualization of data or storage/retrieval of results.

Figure 6: VV&A Overview



Fourteen percent of the VV&A efforts reported depended on the involvement or leadership of the contractor who developed the model. Depending on the procedures that are implemented, errors may be more easily overlooked when contractors VV&A their own models. An alternative view is that the contractor developing the system (and the supporting M&S) has a vested interest in insuring VV&A is conducted rigorously -- the contractor wants the system to perform as required.

VV&A efforts conducted or underway were performed by Program Staff or IPT or by a specified organization within the Program's sponsoring Service on over 25% of the models. Programs such as the C2 Vehicle, ATACMS BAT, and V-22 indicated that they were working with Service organizations with expertise in VV&A, e.g. Army Materiel Systems Analysis Activity (AMSAA) for Army Programs, and were using an iterative

process of comparing developmental test results to model predictions. Further, some programs such as LPD-17 reported use of the DMSO Recommended VV&A Practices Guide.

For about 7% of the models, joint organizations, without a vested interest in the program, were conducting the VV&A. For example, F/A-18E/F and SLAM-ER were putting at least some of their models under the scrutiny of the Joint Technical Coordinating Groups on Aircraft Survivability and Munitions Effectiveness. Such groups have access to domain and subject matter experts and typically have a breadth of experience across platform or weapons systems acquisition programs. In addition, the F-22 Program noted that it was using several models considered part of the Air Force Standard Analysis Toolkit and certified by the Joint Accreditation Support Activity (JASA) and/or the Joint Technical Coordinating Group on Aircraft Survivability. As the 1999 DSB on T&E notes, JASA, which also supported the VV&A efforts of the F/A-18 and AIM-9X programs, has significant expertise in VV&A. The AF Standard Analysis Toolkit with models accredited by JASA may be a significant resource for Program Managers since they do not have to pay for model development or provide the funds for VV&A. One concern is that the M&S in this toolkit may be used beyond the situations for which they were accredited.

The most pervasive theme concerning VV&A from the survey data is that the term "VV&A" has a plethora of different meanings. While some good news concerning VV&A was provided in the preceding paragraph, e.g. the use of joint, independent experts, many models are being accepted without VV&A. Threat models seemed to pose a particular challenge. The most common VV&A approach for threat models was to simply compare with historical intelligence documents.

The 1999 T&E DSB notes that funding and expertise needed for VV&A efforts may be difficult to obtain. Further, the Program Manager is usually under severe schedule pressure so a slip in model availability due to VV&A activities may not be considered acceptable. Finally, although there is no shortage of VV&A policy, i.e. OSD and each Service have VV&A policies, implementation is intended to be "flexible". In other words, the policy documents may not provide the Program Manager with the information necessary to structure a solid and standardized VV&A approach. Undoubtedly, all of these circumstances contribute to the range of VV&A approaches found in the survey.

Conclusion: VV&A policies abound but the nature and depth of VV&A activities varies widely across programs. Availability of expertise and cost and schedule pressures may curtail a program office's intended VV&A practices.

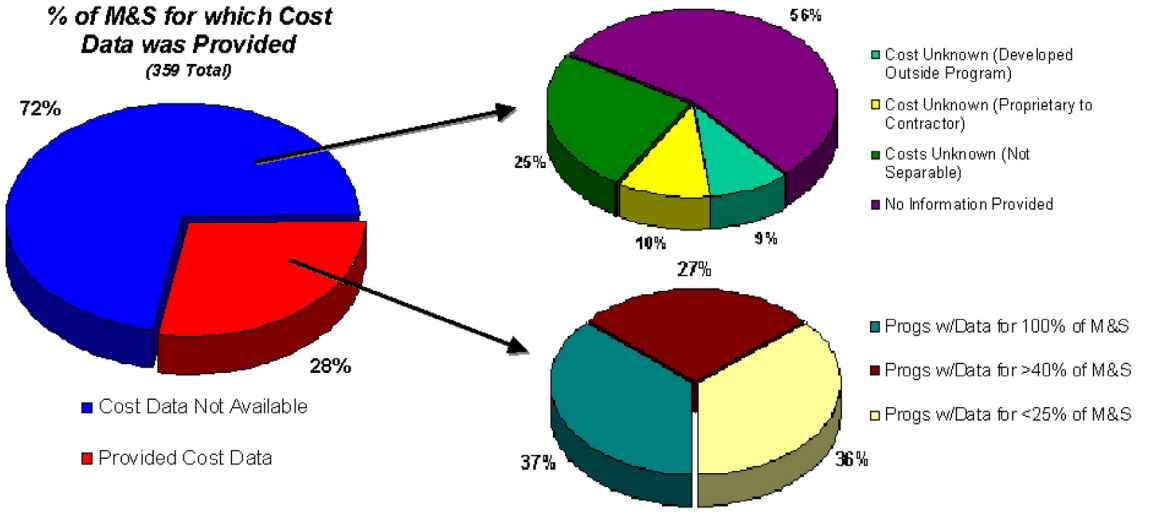
Costs

An important goal of the survey was understanding the costs associated with M&S activities. Better understanding of M&S costs supports several management objectives. These objectives include providing DoD leadership with insight into funds that are being spent; assessing the adequacy of current M&S funding in light of other DoD priorities; promoting more effective and efficient M&S investments; and highlighting potential tradeoffs between M&S investments and those for other T&E methods and/or infrastructure.

The survey confirmed the current lack of management visibility into program expenditures for M&S activities. Figure 7 indicates the availability of cost data on M&S activities within the program offices participating in the survey. Significant reasons for the lack of visibility include:

- Standard cost accounting procedures that do not provide for segregation, reporting or tracking of M&S costs.
- M&S costs that are not included as a reportable DoD Element of Expense.
- Contracts that do not track M&S activities unless a specific model or tool is listed as a deliverable item.
- The costs of multipurpose M&S tools in use by contractors that are reflected in other costs to the government, such as engineering support to the program or delivery of end items.
- Most programs are not required to track, and therefore are not currently tracking, program expenditures specifically for M&S activities.

Figure 7: M&S Cost Overview



- *M&S development and application costs data are not readily available within acquisition programs*

Only 10 of the 21 Programs supplied cost data on M&S development. Collectively, these 10 Programs supplied cost data on 30% of the M&S reported. Only four of the ten cost-reporting Programs supplied cost data on all of the M&S in use by the program. It is impossible to generalize the results displayed on the accompanying graphic to a meaningful statement about the level of investment in M&S other than setting a lower bound and also the fact that the data are readily available. Even for the four programs that did provide complete cost information, it is not possible to draw conclusions. The four programs are a mix of new (LPD-17) and mature (Javelin) and legacy or follow-on efforts (AN/BSY-2, ATACMS-BAT). Since the programs are in different phases of the acquisition process they are likely at different points in their eventual expenditure of M&S funds. The Programs also represent platform, weapons, and C4ISR program types that, as shown previously, vary in the number and type of M&S used.

Figure 8: M&S Cost Summary

Program	Approx. Acquisition Cost	M&S Development Expenditures to Date	Reported M&S exp. to date as % of Total Acquisition Cost	% of M&S with Cost Data
LPD-17	$10B	$38M	<1%	100%
ATACMS/BAT	$5B	$25.2M	<1%	100%
Javelin	$4B	$48M	1.2%	100%
AN/BSY-2	$3B	$58.3M	1.9%	100%
SADARM	$3B	$14.6M	<1%	78%
V-22	$37B	$50.2M	<1%	44%
FAAD C2	$1B	$37.6M	3.7%	40%
SLAM-ER	$.5B	$8.1M	1.6%	21%
F/A-18E/F	$46B	$15.1M	<1%	5%
SBIRS	$8B	$28M	<1%	<1%

M&S as Percentage of RDT&E: The ATACMS/BAT Example

RDT&E Expenditures to Date*	M&S Investment to Date*	M&S Investment as % of RDT&E Expenditures to Date*
$1.46B	$25.2M	1.7%

** Through FY99*

Viewing M&S cost as a percentage of total acquisition cost may be misleading as well. It is unlikely that funds will be spent on M&S evenly over the entire acquisition lifecycle of the program. It is more typical that M&S funds will be required during the RDT&E phase of the acquisition process as opposed to the procurement phase. Hence as an example, the M&S investment as a percentage of RDT&E expenditures to date was calculated.

However, the survey was able to identify several sources of M&S support to the program offices which suggest a list of activities to be considered in developing an estimate of total DoD M&S expenditures. Examples:

- Contractor Support. Survey results suggested that contractors develop and utilize M&S tools from basically four sources in their support of acquisition programs:

    - Generic COTS tools;
    - Contractor-proprietary tools developed internal to the company, funded through Independent Research and Development (IR&D), with applicability across multiple commercial and/or military programs;
    - Generic or proprietary tools further modified by the contractor to fit particular program needs;
    - Custom tools developed (or purchased from others) by the contractor for a specific program purpose or tailored application.

- Lab or FFRDC Support. Service laboratories and product centers, along with several Federally Funded Research and Development Centers (FFRDC), develop and maintain models with broad applicability to Service acquisition programs. Typically, the initial development and routine maintenance of these models are funded within the laboratory or center budget. Acquisition programs pay for the incremental cost of operating the model, and/or any necessary modifications to the model, in support of their specific program needs. In these cases, the cost of such a model to the program should be reflected in a billing and reimbursement record between the Lab and the System Program Office (SPO).

- Service or DoD M&S Repositories. In some cases, the Services and DoD have created central repositories of M&S tools above the Lab level. Typically, models called out for centralized control at the Service level are those with Tri-Service-wide applicability across commands or missions. One example would be more complex, dynamic, high-end models involving the integration of combat, logistics, and threat data in a force-on-force scenario. As in the case of Lab support, individual program offices do not pay for development or maintenance of such models, but are required, to reimburse the owner for support provided to the program. In some cases, a program may need to subsidize directly Lab or Service level development of a large and complex model to simulate an environment or operational scenario necessary to evaluate program effectiveness.

In addition to identifying sources of M&S support to program offices, other methodologies were sought to isolate the cost of M&S activities at the program level. The challenge was posed in the following question: *Where and/or how would a Program Manager find an audit trail leading to government and contractor expenditures on M&S in support of a given program?* After discussion with several experts, including a leading M&S expert at the Defense Systems Management College, a former Director of the Defense Contract Management Command, and a Service Auditor General, it was

concluded that program costs and expenditures associated with M&S activity could not be estimated without a detailed review of a program's work breakdown structure.

Conclusions: At present, data concerning the investment in M&S at the program level is not available to an extent that supports policy formulation and resource allocation. Some opportunities and procedures are available for future use should M&S cost tracking be recognized as desirable.

SUMMARY

- Characterization of Model Types and Uses: Requirements for M&S vary by program type and program maturity. Availability of a common set of M&S could benefit program offices by allowing them to conserve schedule time and funding.
- M&S Management: Some of the management activities that are considered necessary to full realization of the SBA vision are being implemented. These activities are particularly in evidence on the new acquisition programs in the survey. However, implementation of these activities alone is not a sufficient condition for SBA to succeed.
- Validation, Verification and Accreditation Efforts: VV&A policies abound but the nature and depth of VV&A activities varies widely across programs. Availability of expertise, cost and schedule pressures may curtail a program office's intended VV&A practices.
- Costs: At present, data concerning the investment in M&S at the program level is not available to an extent that supports policy formulation and resource allocation. Some opportunities and procedures are available for future use should M&S cost tracking be recognized as desirable.

RECOMMENDATIONS

The following major recommendations are based on the survey data, literature search and interviews. These recommendations were presented to the Undersecretary of Defense (Acquisition, Technology and Logistics) in March 2000.

- Program offices should develop a formal plan early in the program and get buy-in to the plan by the acquisition decision-makers and testing community.

- Program offices should use M&S to aid in test design and make pre-test predictions. Test results should then be used to validate and improve models and simulations.

- Program offices should specify that the models and simulations used in the acquisition process are deliverables under the acquisition contract. The program office should implement measures to insure sufficient visibility and confidence in the results of models and simulations.

- OSD and the Service Acquisition Executives should develop improved techniques to guide the use of M&S in the proposal development and proposal evaluation process.

- OSD should assume a leadership role in determining how to best use M&S to explore interoperability issues. Particular emphasis should be placed on the potential of hardware-in-the-loop and man-in-the-loop simulations.

At the request of the USD (AT&L), these insights coming from this survey were incorporated in the draft revision of DoD 5000.2-R (Mandatory Procedures for Major Defense Acquisition Programs and Major Automated Information System Acquisition Programs). These recommendations are discussed in more detail in the following paragraphs.

The role and value of formal Modeling and Simulation Plans

Of the twenty-one programs surveyed, eleven programs had developed M&S Support Plans. These plans are useful in providing an overview of the M&S tools that are being used by the acquisition programs but do not define the future requirements for acquisition program support. In other words, the plans do not define the technical capability needed or funding requirements for M&S over the course of the acquisition program. Lack of a focus on M&S requirements means that the Program Manager may not have the M&S tools (or the funding and technical expertise) available when needed, for example, to support T&E.

A requirements-focused M&S plan enables the Program Manager to better justify and protect the necessary funding. The 1999 Defense Science Board on T&E noted that *"the sizeable costs associated with the development and employment of M&S capabilities can be daunting to the Program Manager who requires such capabilities as an adjunct to physical testing of a weapon system."* As the DSB report shows, M&S development and usage costs are not well understood even after the investment has been made. Inclusion of funding projections in M&S plans may engender improved assessment of costs and benefits and, certainly, a vision of what kinds of M&S will be needed at what points during the acquisition process.

Developing a requirements-based M&S plan would also facilitate improved responsiveness from the Science and Technology (S&T) community. The survey results indicated that the acquisition community was not using the latest "Best-of-Breed" M&S tools developed by the S&T organizations. For example, outdated versions of hydrodynamics codes were still in use by some programs although the S&T community has greatly improved upon these codes. Defining M&S requirements near the start of an acquisition program would allow the S&T community to better apply its resources.

Another benefit of a forward-looking M&S plan is that it facilitates M&S re-use in time across acquisition phases and across acquisition programs. The survey results indicated that M&S re-use was occurring to a limited degree across acquisition phases on 15 of the

21 programs. 13 programs were using M&S that had been used by other acquisition programs. Often the prime contractor drove this re-use, i.e., a contractor used the same M&S on multiple programs. Sharing of requirement-driven plans among Program Managers could increase opportunities for M&S re-use.

Development of these plans will undoubtedly require more reliance on M&S expertise. Interviews conducted during the M&S survey indicated that PMs who have dedicated M&S staffs or access to M&S Integrated Product Teams (IPTs) may realize a higher return on investment on M&S support. Five of the 21 programs in the survey had M&S staffs or IPTs.

Use of M&S for pre-test predictions; use test results to validate and improve M&S

Programs under the statutory purview of Live Fire Test and Evaluation are required to perform pre-test predictions. For example, AIM-9X, Javelin, and ATACMS BAT are all using M&S for pre-test predictions and using test data to improve the M&S. While the LFT&E statutory requirements apply to systems representing over 80% of all DoD procurement dollars, there are some systems that do not require LFT&E. Similarly, there are also many non-MDAP programs that have no statutory IOT&E requirement either. While the LFT&E program has enforced the discipline of pretest predictions being provided prior to every LFT&E test since its inception, this has not been true of other types of T&E. Further, the 1999 DSB on T&E notes that "verification, validation and accreditation (VV&A) as presently practiced with respect to M&S techniques in general is not sufficiently disciplined to inspire confidence in their use in the T&E process."

There is no shortage of VV&A guidelines in the Services and DoD organizations. The survey results, however, indicated that implementation varies widely. For instance, the survey results documented approaches to M&S validation such as comparison of model results with threat documents or historical data, comparison of model results with test data, and review of M&S output by IPTs. Data presented earlier in this report show that in many cases the M&S pedigree was unknown or uncertain (35%).

Views on what these results imply for the credibility of M&S in acquisition are disparate. Some acquisition executives believe the benefits are outweighed by the cost and schedule implications of VV&A. Others see a rigorous VV&A regimen as essential prior to reliance on M&S-generated results. Requiring use of M&S for pre-test predictions and use of test results to validate M&S is thought by many to be an "80% solution" towards improving the credibility and utility of M&S support without overburdening program schedules and resources.

In addition to requiring pre-test predictions, another logical step is to explore opportunities to better use M&S as a tool in test design. The survey results indicated that few programs were using M&S in this way. As the Deputy Undersecretary of Defense for Science and Technology (DUSD(S&T)), points out, M&S resources like the High Performance Computing Network are applicable and available to help PMs evaluate alternative test designs.

Value of making Models & Simulations deliverables under the acquisition contract

Establishing M&S as deliverables to the government gives the PM staffs an opportunity for insight into engineering, design, and performance trade-offs that is not necessarily available currently. It also provides the test community with a basis for determining when M&S results can be accepted in support, of or in place of, tests. Without the full disclosure and access facilitated by the contract deliverable process, it is generally impossible for the government to base management decisions or test and evaluation adequacy on the results of M&S alone.

A case in point for this new approach is the Evolved Expendable Launch Vehicle (EELV) Program. The EELV Program Office has contractually defined the "insight" concept by requiring that the contractors provide the government access to all of the tools they employ to design, develop, and test their systems. The Program Office engineers assess the adequacy of the contractors' methods, the assumptions which go into their models, how and when the models are applied, and how the data or results from the models are used for design and development decision making. This approach has allowed the PM to gain confidence in each contractor's development activity.

As mentioned earlier in this report, industry is the predominant force in M&S development, use, maintenance and ownership. Over half of the 359 M&S in the survey were developed by industry and industry retained ownership of nearly 40% of the 359 M&S. The majority of these models are viewed as "proprietary." To link M&S and to use them across programs to support "system of systems" evaluations will require that the government have additional insight into the models and the supporting assumptions and architectures. Similarly, using M&S to support T&E objectives means that the Service Operational Test Agencies (OTAs) need access to the M&S and supporting data. Requiring M&S deliverables is one step towards gaining this insight.

Another advantage of specifying M&S as contractual deliverables is that it provides a better basis for tracking the cost of M&S. Opinions on whether or not tracking the cost of M&S is useful are polarized. Many M&S experts believe that tracking M&S costs is not meaningful since M&S is an integral tool in the acquisition process. Others believe that some knowledge of funds invested in M&S is valuable in justifying and protecting M&S investments. An assessment of the benefits of M&S including costs avoided, time saved, risks reduced, and system cost/performance trade-offs made more effectively should accompany tracking of costs.

The cost tracking inherent in specifying M&S deliverables may also benefit industry. The survey results showed that many contractors were investing corporate Internal Research and Development (IR&D) funds in developing M&S including significant investments in Hardware-in-the-Loop (HWIL) and Man-in-the-Loop (MITL) capabilities. Also the survey results showed that PMs were able to make extensive, cost effective use of these HWIL/MITL simulations. However, as profit margins and returns on investment in DoD-related activities spiral downward, corporate Chief Financial Officers (CFOs) are

reluctant to condone such investments of scarce IR&D funds. Improved cost tracking through the contractual deliverable process may allow companies to realize a better return on investment in these expenditures of corporate IR&D.

Requiring that M&S become deliverables has other implications for the contracting community. As shown previously in this report, only 11 of the 21 programs in the survey included M&S activities in the contractor's Statement of Work. Of those 11 programs, only one incentivized the contractor for performance on M&S related tasks. In specifying M&S as deliverables, the PMs should consider increased use of an incentive structure for contractually responsive M&S delivered on time and within budget.

Clearly, contractors will be reluctant to make certain models and simulations deliverables for fear that the intellectual property and competitive advantage inherent in these models will be subject to dissemination to competitors. This situation will obviously require extreme care in contracting. It may even require the development, at government expense, of industry-wide M&S that are distinct from the proprietary design M&S used for competitive advantage. Moreover, where to draw the line in terms of making M&S deliverables needs to be assessed. Questions such as "are only newly developed M&S required to be deliverables", and "is the contractor support of the M&S as well as the M&S themselves required to be deliverables", will have to be answered.

The Role of Models and Simulation in the Proposal Process

The proponents of Simulation-Based Acquisition (SBA) argue that M&S should be introduced into the acquisition process as early as possible and used in an iterative manner throughout the course of the acquisition program. In the context of this goal, envisioning the contractor's models and simulations as substantive parts of the proposal, and envisioning the government's models and simulations as substantive proposal evaluation tools is logical. The contractor and government need to specify those M&S tools at the start of the acquisition process, perhaps even in the Request For Proposal (RFP).

Such specification is likely to be a useful first step towards accomplishing the still elusive SBA vision. M&S used in evaluating proposals are likely to be used by contractors in developing the proposals. Then, having made the investment in particular M&S for the proposal, the contractor is likely to continue to use them at least in the early stages of system design and development.

There is a need to identify the M&S that will be used for evaluation purposes. Even in a relatively small sample of 21 programs, 359 M&S tools were in use. Of these 359, over 100 were categorized as Combat M&S, including campaign, mission, engagement, and models, that are used extensively in the early stages of system acquisition. This large collection of M&S represents an even larger collection of underlying assumptions, input data, and computational techniques.

In addition to specifying the technical M&S that will be used in proposal evaluation, the government should specify the cost or affordability models that will also be used. *Despite the DoD's emphasis on Cost as an Independent Variable (CAIV), the survey results revealed that few M&S were being used to support CAIV analysis.*

The use of Models and Simulation to explore interoperability issues

Interoperability is one of the major stated goals in the DoD today. It is a difficult goal to pursue and for which to quantify success. In some cases, M&S may offer one of the few viable means for cost effectively and time efficiently analyzing and testing interoperability. The M&S survey results indicate that few programs were using M&S or had plans to use M&S to evaluate the interoperability of that program with other programs in acquisition. In fact, the Space-Based Infrared System (SBIRS) was the only program of twenty-one that reported modeling in support of joint systems interoperability.

Some M&S tools offer extraordinary potential to help realize the vision of interoperability. For instance, HWIL and MITL simulations are an emerging part of the T&E infrastructure that can prove invaluable in this context. These capabilities support repeatable test and training events among system or mission area components in a cost effective and schedule efficient manner. A case in point reported in the survey is the integration of the SLAM-ER HWIL simulation with the F/A-18 MITL simulator that enabled a pilot to train and analyze delivering a weapon to its target. This example portrays the most elemental level of interoperability testing and training since the SLAM-ER and F/A-18 were designed to satisfy well-specified interface requirements relative to one another. However, this first step is indicative of the opportunity to examine "system of systems" interactions by linking multiple HWIL and MITL capabilities.

Another tool that may be useful in supporting interoperability objectives is a collaborative environment, i.e., an overarching architecture that facilitates the linkage of M&S across distributed locations and organizations. The survey results discussed above indicate that less than 30% of the programs had established collaborative environments and that a significant number of the respondents were even unfamiliar with that term.

Interoperability may also require use of common M&S across programs to ensure a consistent frame of reference. The survey results showed that of the 359 models and simulations in use across 21 programs, at least twenty-five M&S were being used by more than one program. If these M&S were to be used across programs to support interoperability activities, several questions would need to be answered. These questions include whether these M&S are "best of breed," what are the strengths and weaknesses of the M&S, and what are the limits on extension and application of the M&S. The Air Force Standard Analysis Toolkit, a collection of M&S that have been accredited for use for specific purposes, exemplifies an approach that might be useful for interoperability needs.

NEXT STEPS

A version of DoD 5000.2-R that incorporates the general recommendations discussed above is now in coordination. In addition, USD(AT&L) and DOT&E have agreed that M&S plans will be more thoroughly examined during program reviews and during reviews of Test and Evaluation Master Plans (TEMPs) and other test plans. Further, DOT&E plans to work with DUSD(S&T) to develop M&S for use in operational test design and to improve migration of M&S applications from the S&T community to program offices.

Discussions of the survey results between DOT&E and the three Service Acquisition Executives, produced the idea for a series of Pilot Projects. The Pilot Projects will examine the opportunities for using M&S to effectively support the acquisition process. Each Service has nominated one program for consideration. The projects involve (1) characterizing the data needed to support acquisition decision making, (2) categorizing the potential opportunities for M&S support in generating these data, and (3) describing the risks and benefits of using M&S-generated data in support of specific acquisition decisions. The end result of the Pilot Projects will hopefully be a methodology that can be used to guide the development and application of M&S to support system acquisition.

The dynamic field of M&S has the potential to improve the acquisition process. For some programs, particularly those requiring system of systems engineering, M&S tools may offer a practical means of examining and exercising all parts of the system repeatedly in an integrated manner. To make better use of M&S, PMs need improved planning, funding, contractual, and education/training support. The changes discussed above should help to expand and improve the use of M&S in acquisition and help the DoD continue to evolve towards its goal of SBA.

ACKNOWLEDGEMENT

The authors also wish to express their appreciation to all those program managers who actively participated in this survey and hope that this effort will yield a significant benefit to them and to the larger Department of Defense community.

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DoD M&S Glossary

DOT&E FY98 Annual Report to Congress

Simulation Based Acquisition: A New Approach, DSMC (December 1998)

"*Taxonomy of M&S Types and Applications in the System Acquisition Process, December 1998."* This taxonomy is contained in *"A Roadmap for Simulation Based Acquisition,"* produced by the Joint Simulation Based Acquisition Task Force.

Appendix A

SURVEY SUPPLEMENT

Survey Supplement
A literature review and interviews supplemented the survey results with some key M&S experts. A representative list follows.

Documents reviewed:
DSB Task Force on Simulation for Innovation (1998)
Joint Simulation Based Acquisition Task Force Report for the DoD EXCIMS (1998)
DDR&E Acquisition Task Force on M&S (1994)
DTSE&E Study on Effectiveness of M&S in Weapon System Acquisition (1996)
DSMC System Acquisition Managers Guide for the Use of M&S (1994)
Simulation Based Acquisition: A New Approach (DSMC 1998)
NRC 1998: Statistics, Testing and Defense Acquisition
Program simulation support plans (SSPs)

The Study on Effectiveness of M&S in Weapon System Acquisition completed in 1996 for the Director of Developmental Test, System Engineering, and Evaluation (DTSE&E) was the most similar in purpose and scope to this effort, however, it provided primarily anecdotal data on the application of M&S within a few programs. In addition, the cost data discussed were in terms of expected cost savings from use of models in place of tests and so were not consistent with the intent of this effort.

The Simulation Support Plans provided by the Program Offices were an invaluable source of information in that they generally contained more detailed descriptions of the M&S than the survey inputs and provided information about how the M&S were used in conjunction with one another and with other program activities such as T&E. An area of concern is that these plans did not contain a requirements roadmap detailing how the M&S will be matured and describing the funding necessary to do that.

Additional interviews:
DMSO (Col Kenneth Konwin, et al)
Office of the Assistant Secretary of the Army (Acquisition, Logistics and Technology) (Ms. Ellen Purdy)
SAF/XOC (Dr. Jacqueline Henningsen, et al)
DSMC (Mr. Randy Zittel)
DOT&E/IDA (Dr. David Sparrow)

The interviews with recognized M&S experts provided a much broader perspective of the evolution of M&S than the survey data did. In particular, the discussions with Defense Modeling and Simulation Office (DMSO) and Army Secretariat for Research, Development, and Acquisition (SARDA) personnel were invaluable in illuminating challenges in interpreting the survey data, informing of M&S trends, describing lessons learned, and providing referrals to other M&S experts.